Be/W mixed material experiments

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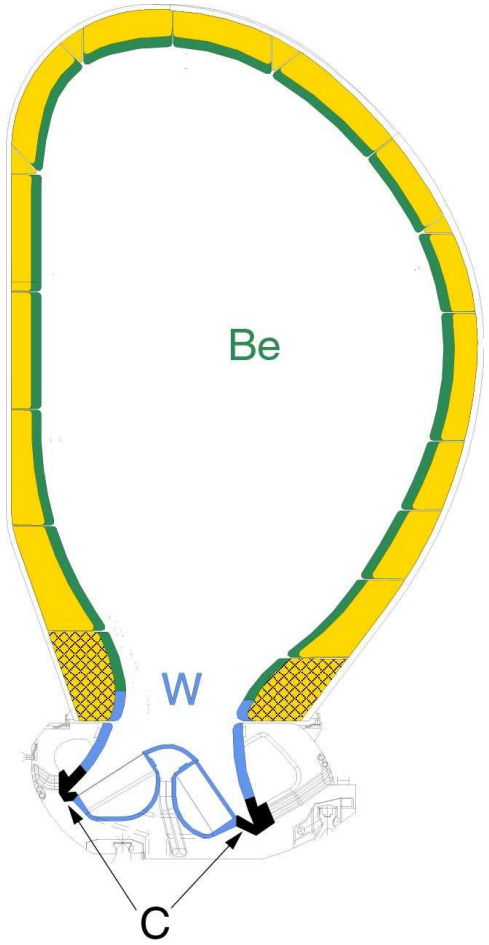
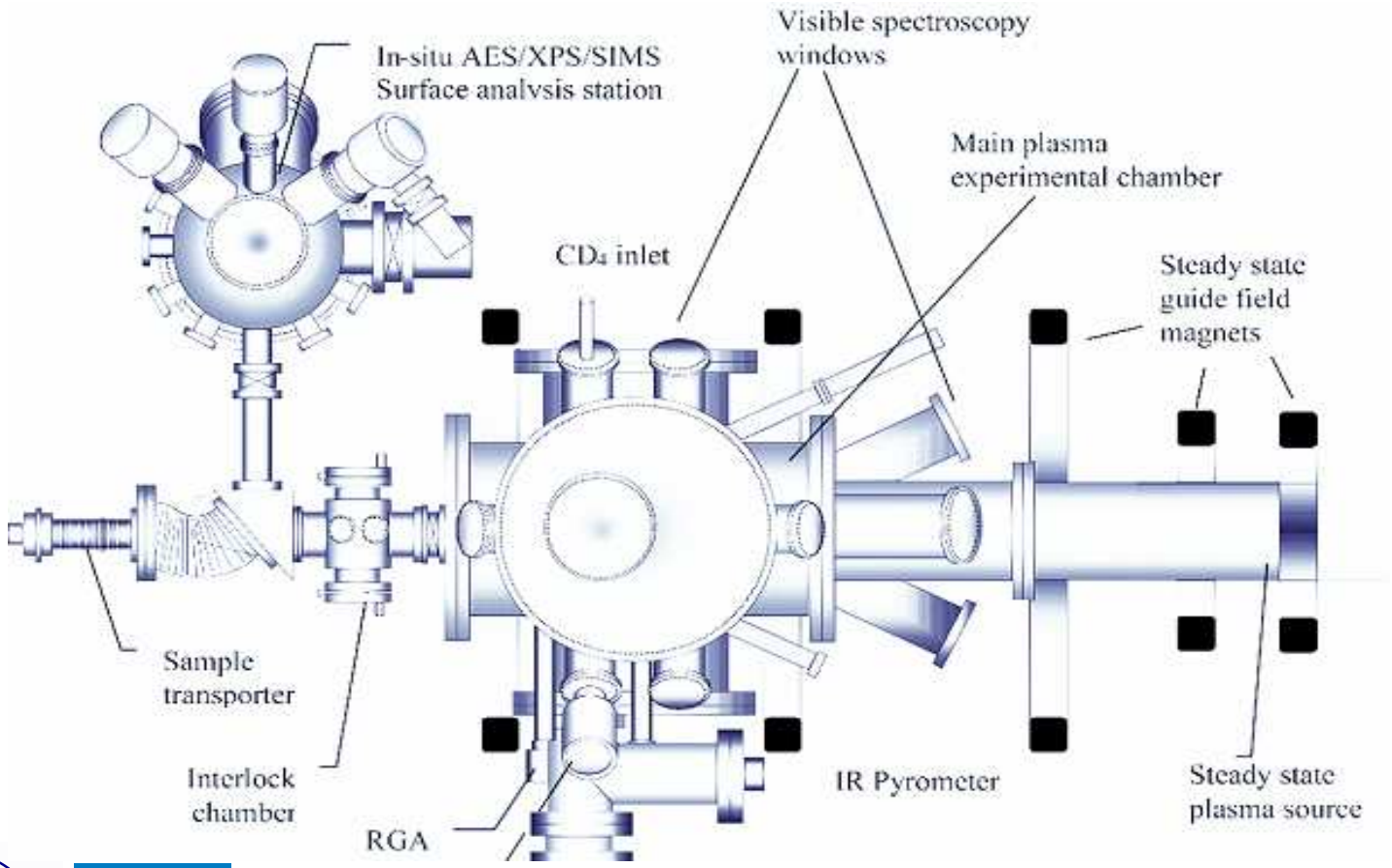
Motivation

- UC San Diego PISCES and EFDA are investigating the influence of Be plasma impurities on exposed materials interactions relevant to ITER.
- The ITER design: Be first-wall, W divertor, C (graphite) strike points.
- Diverted plasma expected to be 'dirty': Eroded Be impurity conc. up to 10 %.
- Amongst others, Be/W PMI is an issue.



PISCES-B can investigate Be-W PMI relevent to ITER divertor

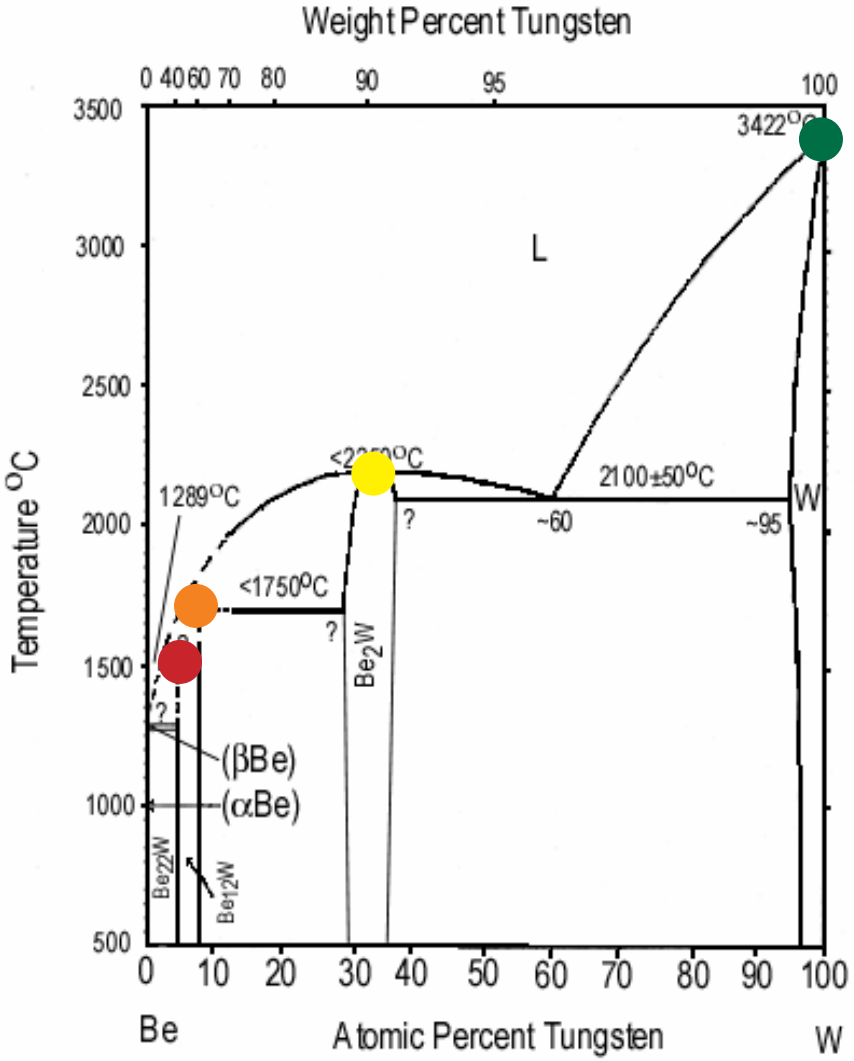


Be layers on plasma exposed W surfaces?

- Be can alloy with W
- W structural integrity is reduced at significantly lower temperatures. Liq. phase precipitates at

Be_2W ~ 2200 ℃
$Be_{12}W$ ~ 1500 ℃
$Be_{22}W$ ~ 1300 ℃

- ITER should be concerned about these alloys since little PMI data on Be-W exists.

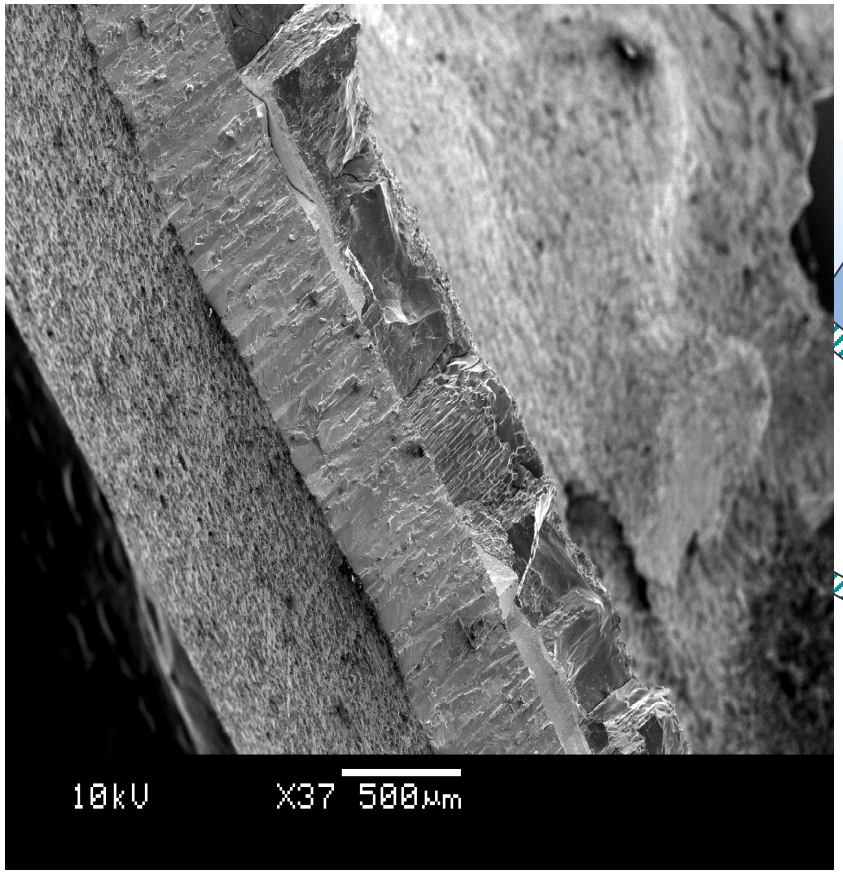


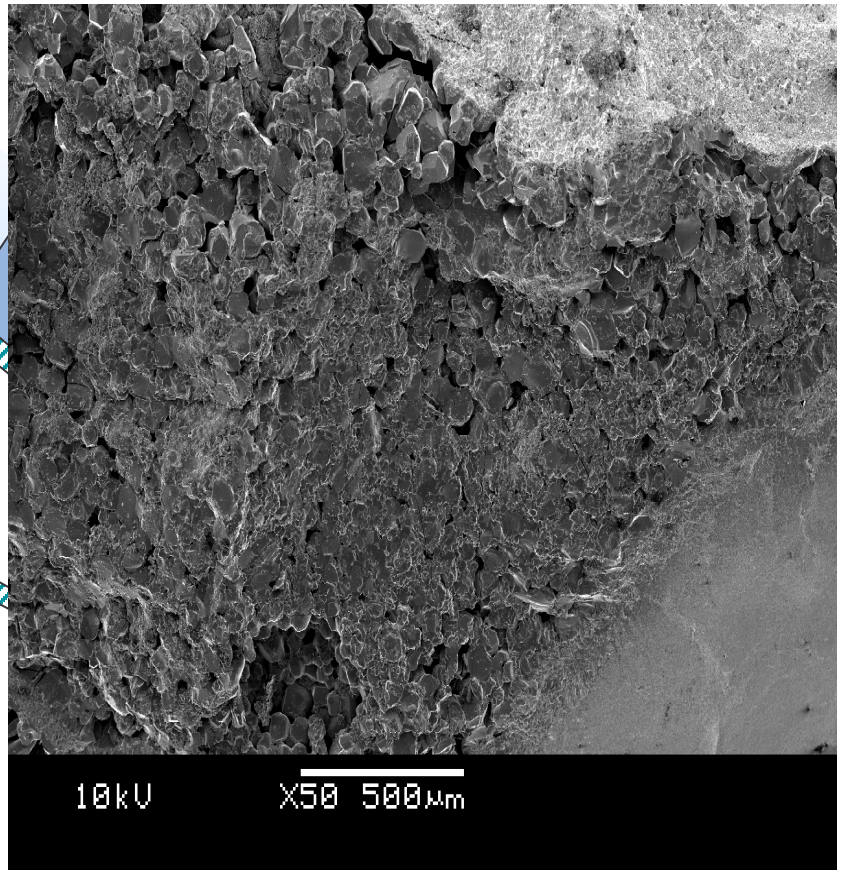
From H. Okamoto and L.E. Tanner, in "Phase Diagrams of Binary Tungsten Alloys", Ed. S.V. Naidu and P. Rao,Indian Institute of Metals, Calcutta, 1991.

Intact W wall
(97%W, 3%O)

Inner wall coating
(4% W, 95% Be, 1%O)
$Be_{22}W$?

Crucible wall fragments from
Be rich failure zone
(9% W, 70% Be, 14% C, 7% O) $Be_{12}W$?





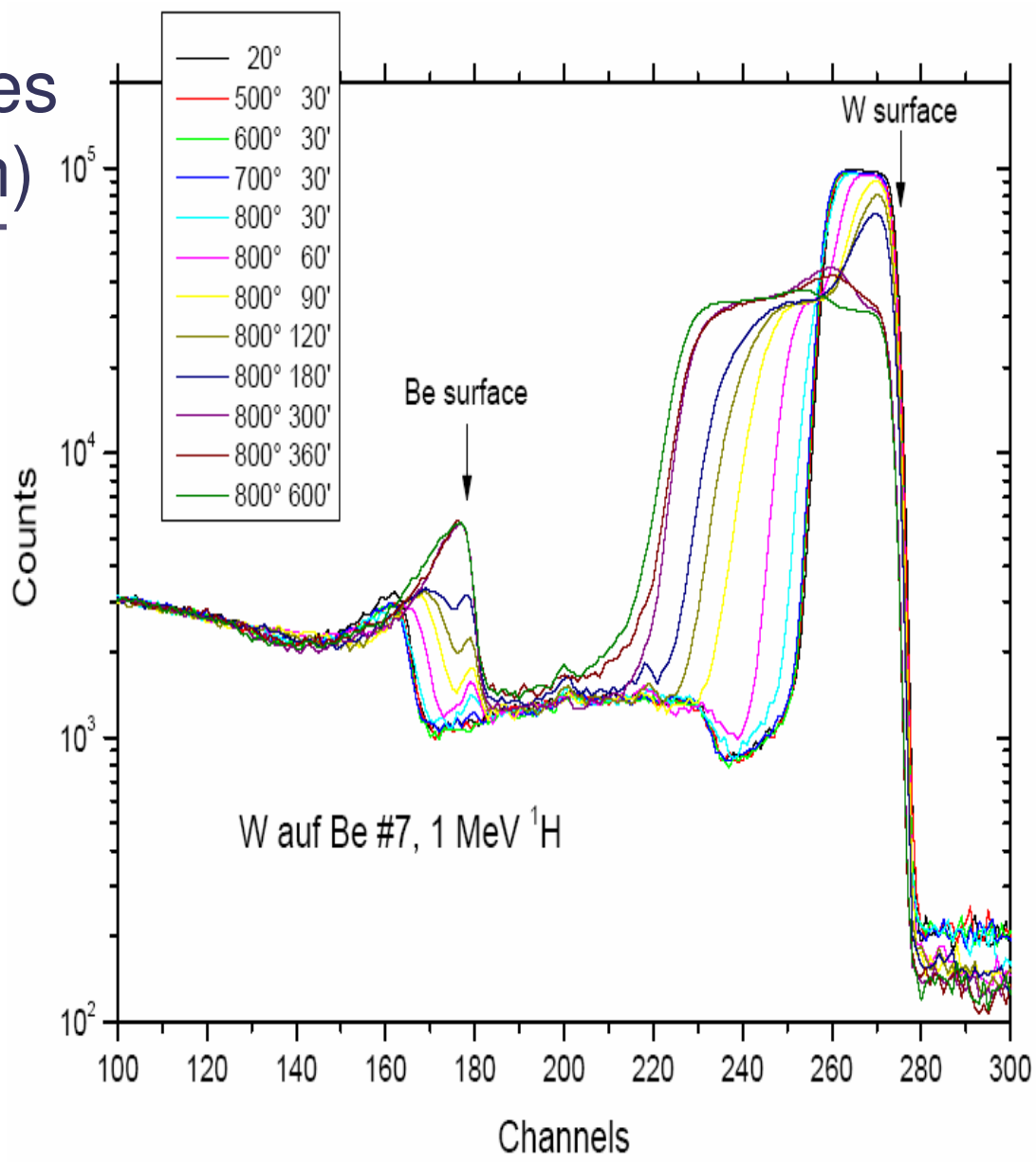
Alloy formation studies (US-EU collaboration)

230 nm deposited W

- No visible reaction up to 700 °C
- Alloy formation starts at 800 °C
- Annealing in vacuum up to 800 °C for up 600 min
- RBS ion beam analysis H (1 MeV)

Polished Be substrate

Be diffuses through Be/W alloy and W layer to the surface

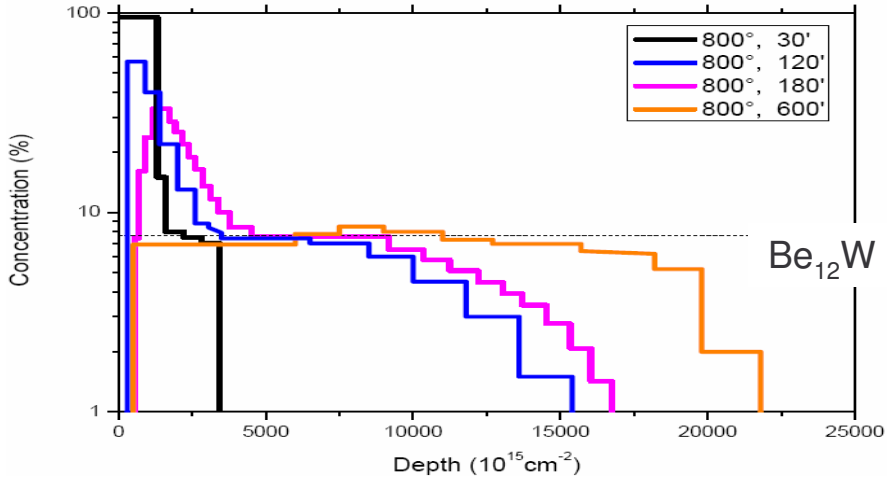


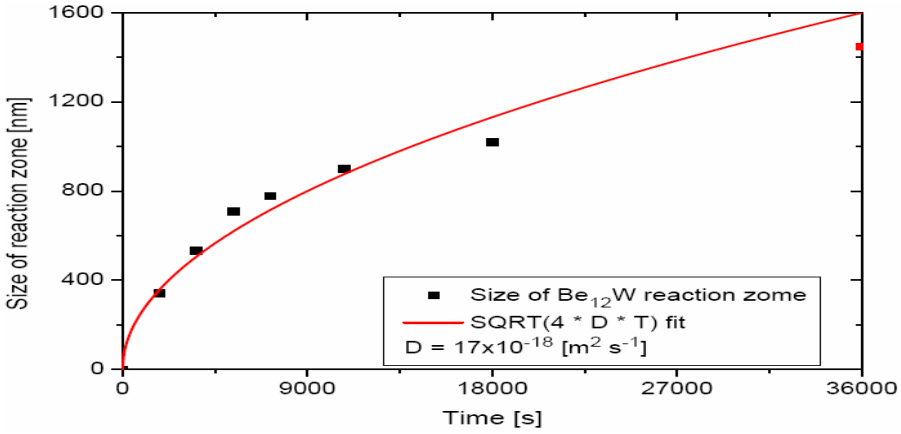
Is layer growth diffusion limited?

- Reaction controlled by chemical potential or diffusion not clear.

  A. Vasina et.al, Russian Metally, **1**(1974)119.

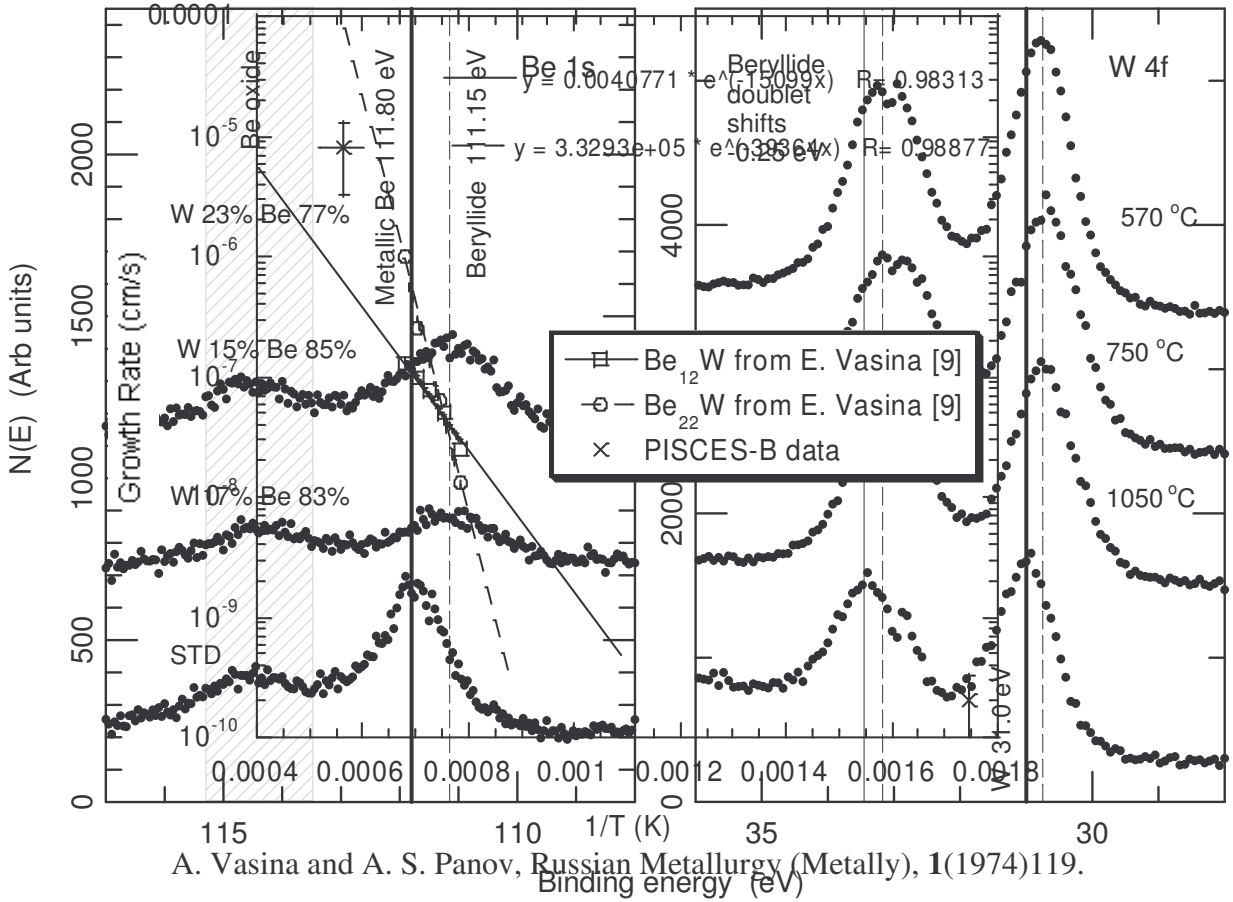
- After 600 min the whole layer is transformed into $Be_{12}W$
- The $Be_{12}W$ phase seems thermodynamically more stable than Be_2W and $Be_{22}W$
- $D_{800℃}$ ~ 1.7 10^{-13} cm^2/s





PISCES plasma exposure induces beryllides (570-1050 °C).

- XPS confirms beryllides
  (E.g. Wiltner *et al.* J. Nucl. Mater. **337-339** (2005) 951)
- AES Concentrations are close to $Be_{12}W$
- Need to investigate PMI layer growth
- Will diffusion limit layer growth under plasma operation?



A. Vasina and A. S. Panov, Russian Metallurgy (Metally), **1**(1974)119.

Retention and blistering w/ & w/o BeW layers

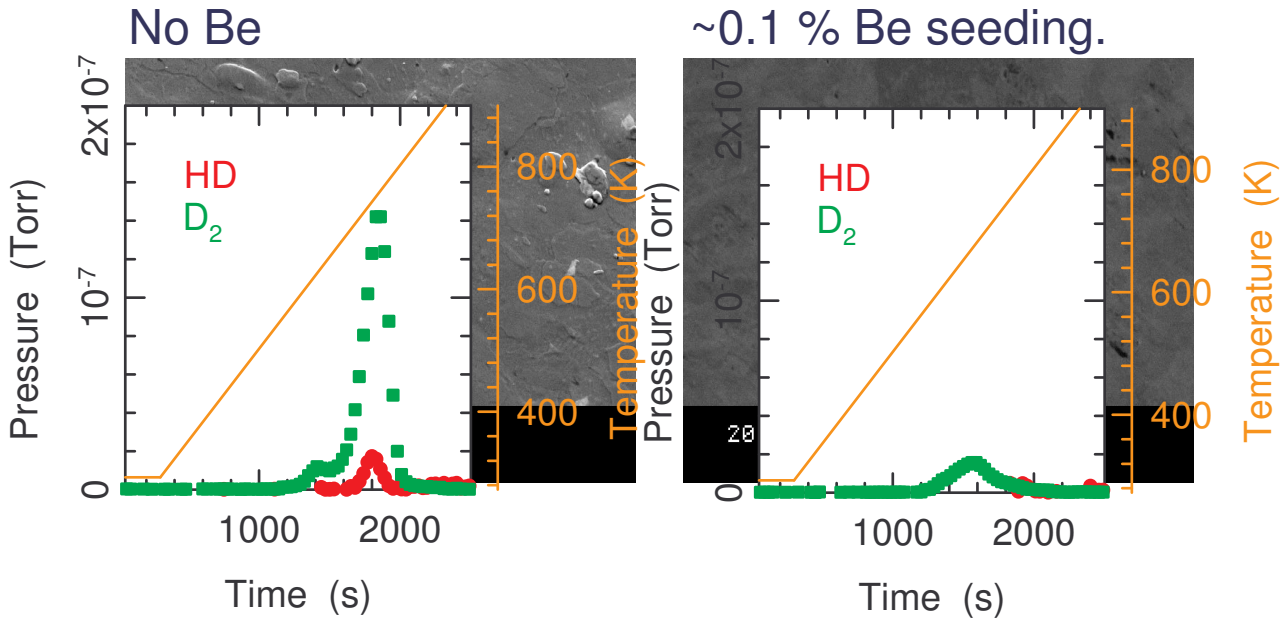
- Initial results suggest that Be impurity flux inhibits blistering. Why?
- Retention in Be coated W is is found to be comparable to retention in unblistered W at temperatures of 300 ℃ and 1000 ℃.

E_{ion}: 75 eV

T: ~ 300 ^{o}C

Γ_{D}^{+}: 1 x 10^{22} m^{-2} s^{-1}

Fluence: 5 x 10^{25} m^{-2}



Summary

- Be-W PMI not well understood. Important for ITER & JET.
- Be-W interaction produces low melting point (< 1750 ℃) phases.
- The $Be_{12}W$ phase seems more stable than Be_2W and $Be_{22}W$.
  Observed with WDS, AES, XPS (UCSD) and RBS (IPP).
- Be-W layer growth occurs at (~800 ^{o}C). Possibly diffusion limited.
  Activation energy to be determined (IPP) by further phase formation vs temperature studies.
- PMI can induce beryllides at even lower temperature (570 ^{o}C)
  Layer growth studies are required (PISCES).
  Is PMI diffusion limited or kinetics controlled?
- Be-W layer reduces blistering/retention (~300 ℃). No blistering/retention (~ 1000℃). More data needed. (PISCES)
  Retention consistent with unblistered W.